Forum for Electromagnetic Research Methods and Application Technologies (FERMAT)

NEW ADVANCES IN GAIN MEASUREMENTS IN NON-ANECHOIC SITES: APPLICATION TO NARROW BAND MONOPOLES

Razvan D. Tamas (1,2)

(1) Department of Electronics and Telecommunications,
Constanta Maritime University,
C.P. 202, O.P. 2, 900780 Constanta, Romania

(2) Doctoral School of Electronics and Telecommunications,
Politehnica University of Bucharest,
Bd. Iuliu Maniu 1-3, Sect. 6, 061071, Bucharest, Romania

Email: razvan.tamas@cmu-edu.eu, tamas@ieee.org

***Abstract*— Previously, the author has described a method for measuring the antenna gain in non-anechoic sites. The effects of reflection and diffraction on the neighboring objects can be dramatically reduced by averaging, over a set of distances, a normalized transfer function of the system consisting of the antenna under test and the measuring antenna. The method was successfully tested on dipole type, ultra-wide band antennas. This paper, presents further results on measuring narrow band, monopole antennas. It comes out that averaging does not remove the effect of the diffraction on scatterers close to the radiating element, such as the edges of the antenna ground plane; conversely, it reasonably reduces the effects of scatterers placed at several wavelengths away from the antenna under test.**

Keywords— Antenna gain; monopole antennas; indoor measurements; averaging methods

Razvan D. Tamas was born in Navodari, Romania, on May 10, 1970. He received the Ph.D. degree jointly from *Politehnica* University of Bucharest, Romania, and from Institut Polytechnique de Grenoble, France, and the Habilitation degree *(Habilitation à Diriger des Recherches)* from Institut Polytechnique de Grenoble, France.

He is currently a Professor, head of the Electronics and Telecommunications Department at Constanta Maritime University, Romania, and a Ph.D. supervisor with the Doctoral School of Electronics and Telecommunications at *Politehnica* University of Bucharest, Romania. He was formerly a Senior Researcher with the Navy Scientific Research Center of the Military Equipment and Technology Research Agency, Romania. He also worked with the Institute of Microelectronics, Electromagnetism and Photonics of Grenoble, France on the R.N.R.T. AUBADE project and he was an Invited Professor with Université de Rennes 1 and Université Joseph Fourier, France. His field of interest includes antenna theory, numerical methods for electromagnetism, time-domain characterization, electromagnetic compatibility, and naval communication systems. Dr. Razvan D. Tamas is a Senior Member of the IEEE.

I. INTRODUCTION

➢Antenna gain is generally measured either in an anechoic chamber or in an open area test site (OATS) [1].

➢Antennas providing a short time-domain response can be measured in a multi-path environment by applying a time-domain gating on the measured data, in order to remove the effects of reflection and diffraction on the neighboring objects [2], [3], [4].

➢An alternative method for measuring the gain of an antenna in a multi-path environment has been presented in a previous work [5].

➢The measuring antenna is placed at different distances away from the measuring (calibrated) antenna, and $|S_{21}|$ is measured and multiplied by the current distance; an average over that set of distances is then calculated, in order to extract the gain.

➢The distance averaging method takes an obvious advantage over the traditional measuring techniques when evaluating an antenna gain in situ e.g., for large, low-frequency radiating systems. Far-field constraints can also be relaxed by using the distance averaging technique [6].

➢The method was mainly validated on ultra-wide band antennas [5], [7]. This work shows that the proposed method can be applied to narrow band, monopole antennas on finite size ground planes.

II. DIFFRACTION EFFECT AND DISTANCE AVERAGING

For a dual path transmission including a scatterer (Fig. 1), a normalized transfer function can be defined as

$$f_{diffraction}(r) = 1 + A_{s,h} \cdot \frac{r}{s'} \cdot \exp(jk_0 r) \cdot \exp(-jk_0 r_i),$$

with $A_{s,h} = D_{s,h} / \sqrt{s}$ and $D_{s,h}$ the soft/hard diffraction coefficient [8].

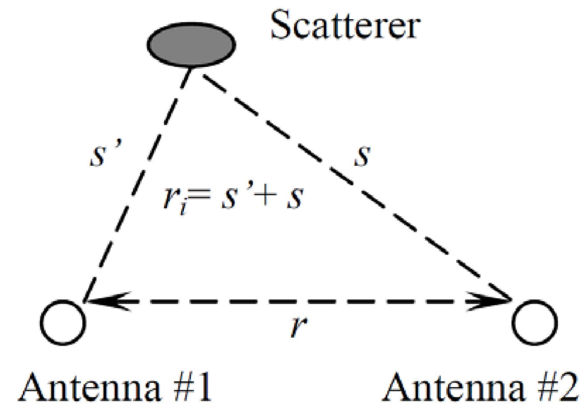

Fig. 1 Dual-path propagation

By increasing the distance r between $r_{\min}$ and $r_{\max}$ an average figure can be computed as

$$F_{diffraction}(r_{\min}, r_{\max}) = \frac{1}{r_{\max} - r_{\min}} \int_{r_{\min}}^{r_{\max}} \left| f_{diffraction}(r) \right| \mathrm{d}r$$

By properly choosing the distance range for averaging the effect of the multipath transmission can be reduced [5] i.e., $F_{diffraction}$ can be made close to 1, as it would be in the free space.

When measuring a monopole antenna on a finite size ground plane, averaging should not remove the effect of the diffraction on the ground edges, as it is part of the antenna radiation. In that case, $F_{diffraction}$ should be constant and close to $f_{diffraction}$ in the far-field zone.

Both types of incidence at 900 MHz were investigated i.e., electric or magnetic field parallel to the diffracting edge. The minimal distance was chosen 1 m and $r_{\max}$ ranged between 1.05 m and 1.5 m.

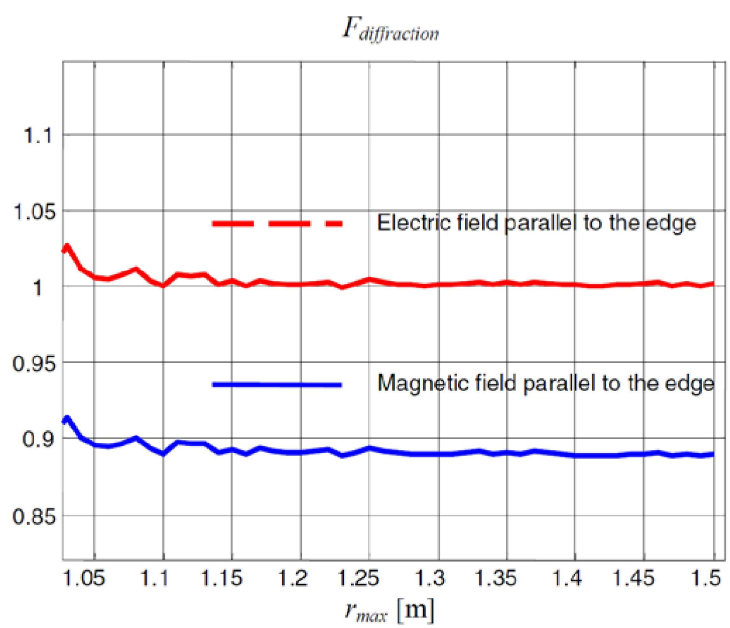

Fig. 2 Average transfer function: *s'*=1 m

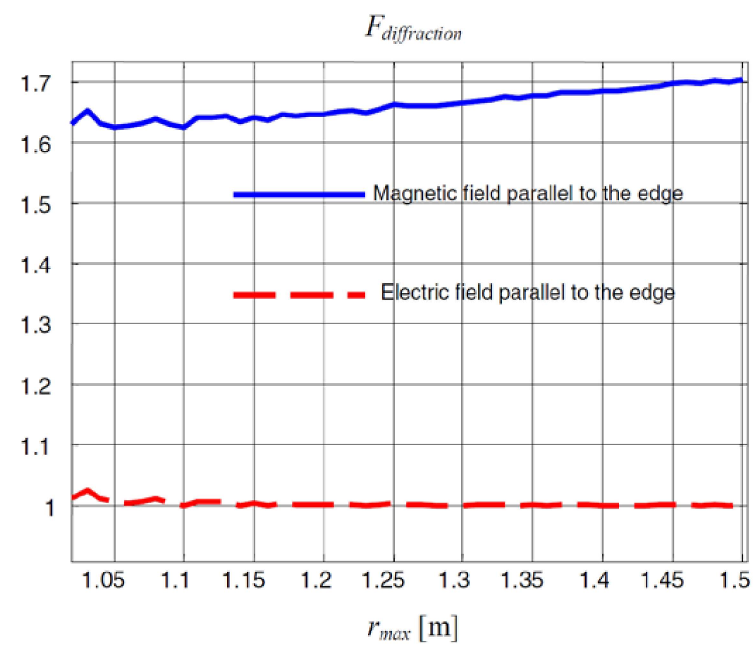

Fig. 3 Average transfer function: *s'*=5 cm

III. RESULTS

A monopole on a square ground plane with a side length of 10 cm was chosen as an antenna under test. The whip length of 8.4 cm makes it possible to use such an antenna around 800 MHz and 2.4 GHz, respectively

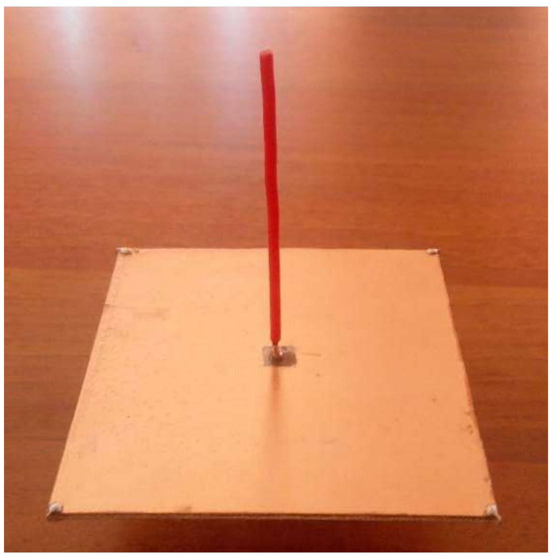

Fig. 4 Antenna under test

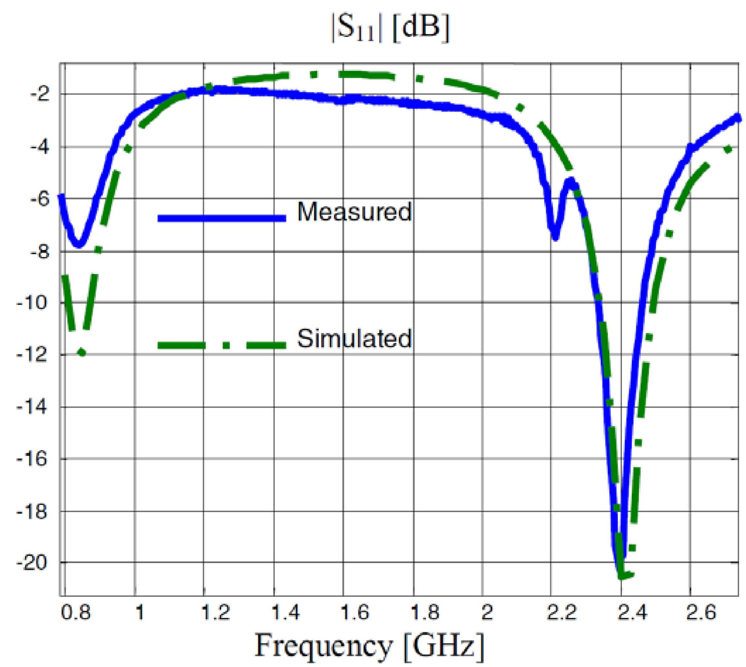

Fig. 5 Input reflection coefficient

As a reference for assessing the accuracy of the method, the antenna under test was firstly measured in an open area test site (OATS).

Measurements were performed for several distances between antennas in the range 0.5 to 1.5 m. As expected, the transfer function defined as $(r/r_0)|S_{21}|$ does not essentially change with the distance.

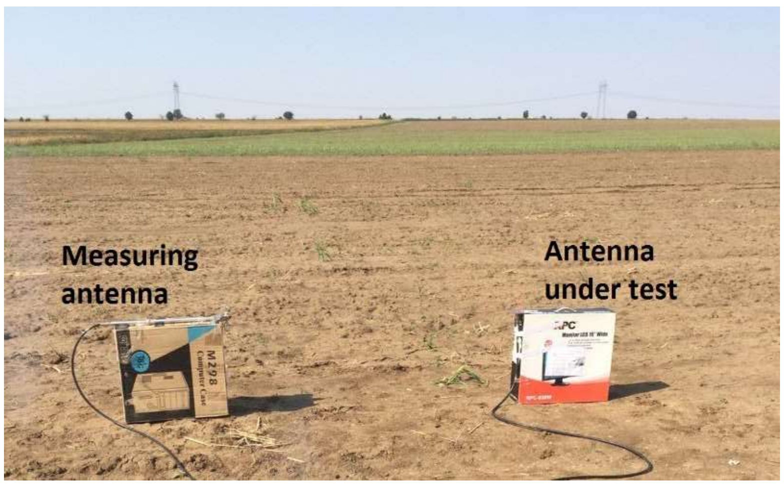

Fig. 6 Outdoor measuring setup

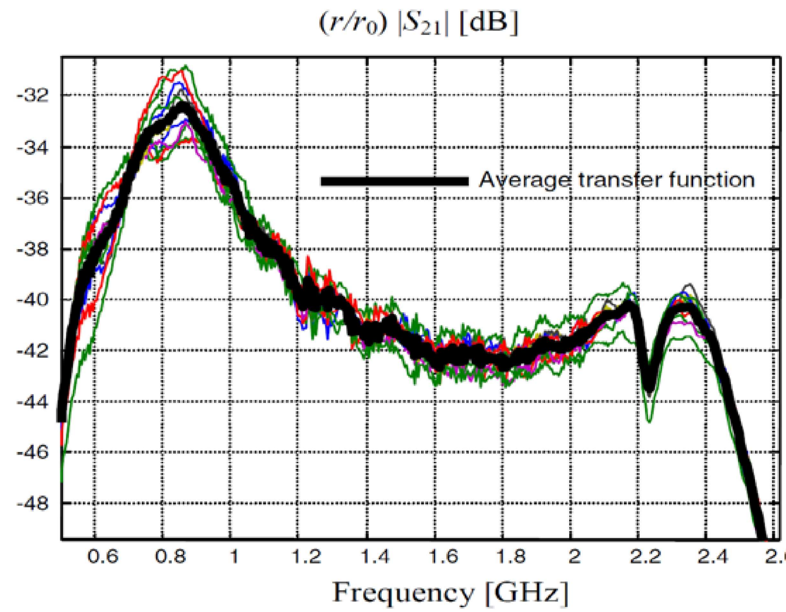

Fig. 7 Transfer function at different distances versus average transfer function: outdoor measurements

The same setup was used for indoor measurements with the distance averaging method. In order to calculate the average transfer function [5], the antenna under test was moved away from the measuring antenna within a distance range between 0.5 m and 1.2 m. The first set of measurements was performed in the test room as it was; for the second set of measurements a supplementary scatterer was placed 0.5 m away from the axis that relies the two antennas and 0.7 m away from the measuring antenna. The scatterer consists of two perpendicular, plane reflectors of 10 cm by 7 cm.

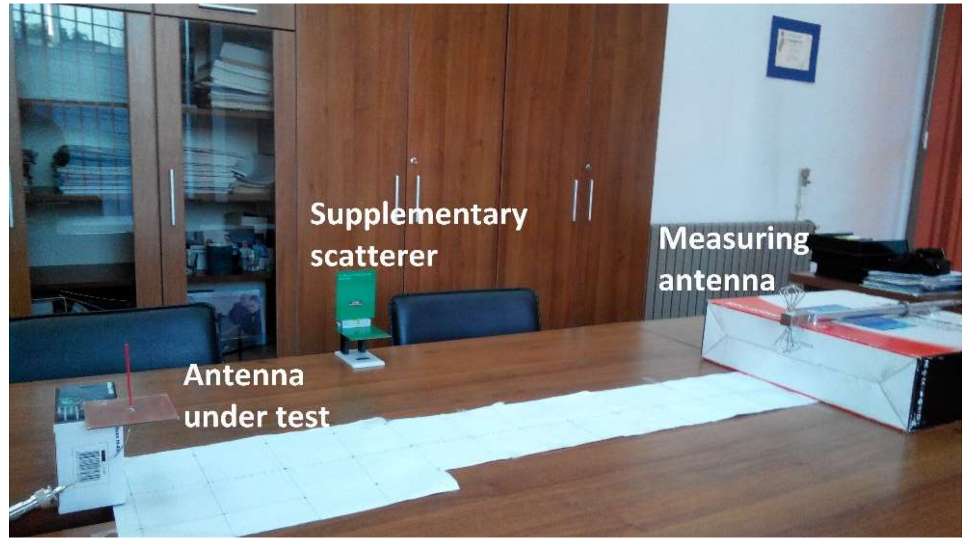

Fig. 8 Indoor measuring setup with a supplementary scatterer placed between antennas

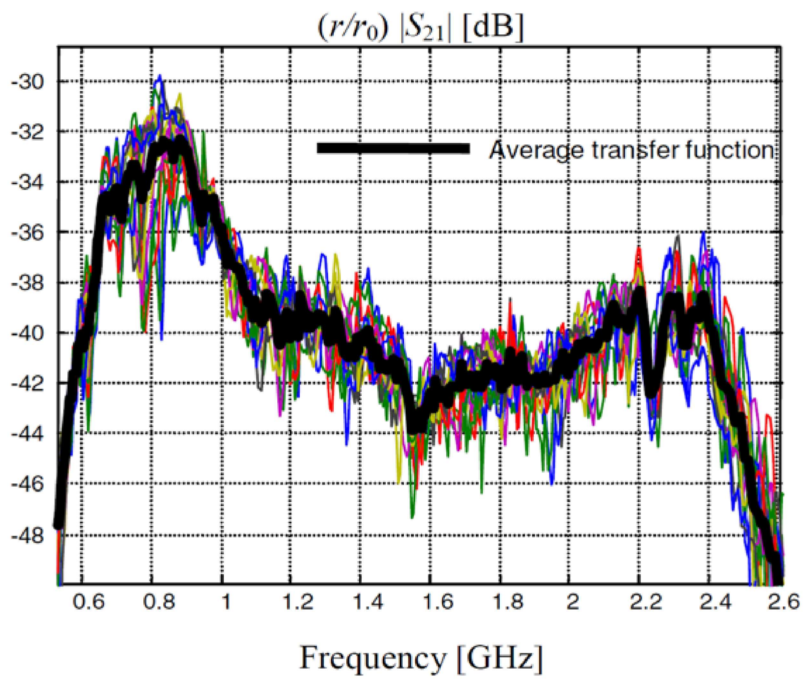

Fig. 9 Transfer function at different distances versus average transfer function: indoor measurements without supplementary scatterer

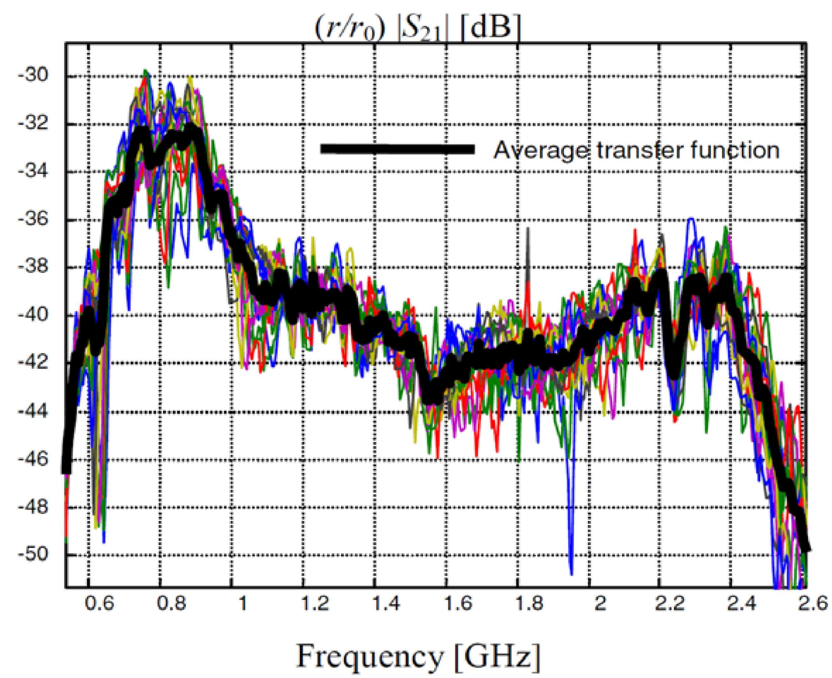

Fig. 10 Transfer function at different distances versus average transfer function: indoor measurements with a supplementary scatterer

The gain of the antenna under test can be extracted from the average transfer function [5],

$$G_{AUT} \cong \frac{r^2 \cdot \left|S_{21,average}\right|^2}{G_m\left(1-\left|S_{11,AUT}\right|^2\right)} \cdot \left(\frac{4\pi}{\lambda}\right)^2$$

The differences between the gain figures measured in the OATS and in the non-anechoic site do not exceed 1.5 dB. A maximal difference of 0.5 dB can be noted between measured data with and without the supplementary scatterer.

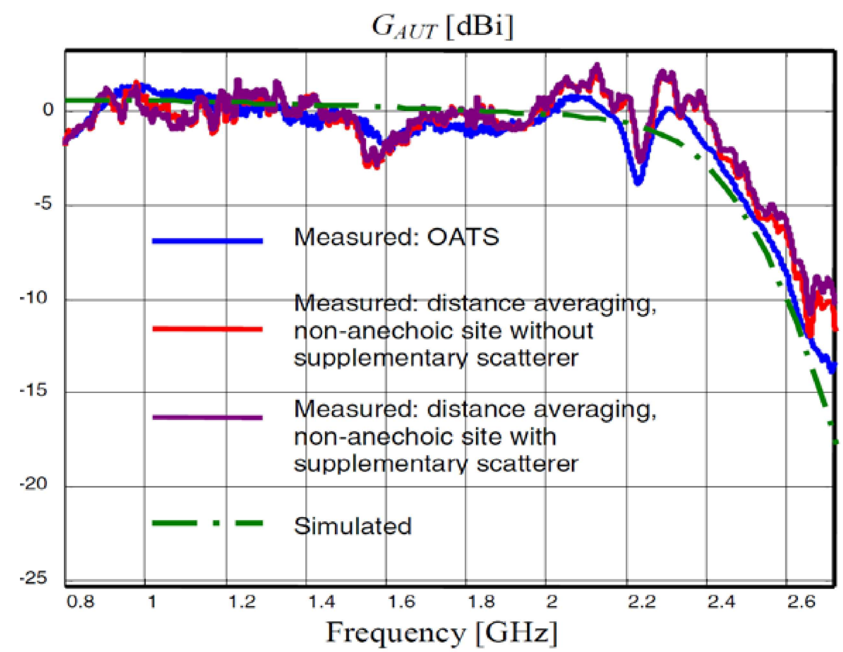

Fig. 11 Gain of the antenna under test: measurements versus simulation

CONCLUSION

➢ **It was showed that the distance averaging technique can also be used for measuring the gain of narrow band, monopole antennas.**

➢ **The effect of the diffraction on the ground plane edges is not removed by averaging and is therefore taken into account as part of the antenna radiation.**

➢ **The distance averaging method led to accurate result, compared to the measurements in an open area test site.**

➢ **Supplementary scatterers placed far enough from the measuring setup do not essentially impinge on the accuracy.**

➢ **The method can also be used for radiation pattern measurements with an appropriate two-axis rotator for the antenna under test.**

REFERENCES

[1] S. Eser, L. Sevgi, “Open-Area Test Site (OATS) Calibration”, IEEE Antennas and Propagation Magazine, vol. 52, pp.204-212, June 2010.

[2] R.V. De Jough, M. Hajian, L.P. Ligthart, “Antenna time-domain measurement techniques”, IEEE Antennas and Propagation Magazine, vol. 39, pp.7-11, October 1997.

[3] J.D. Krieger, E.H. Newman, I.J. Gupta, “The Single Antenna Method for the Measurement of Antenna Gain and Phase”, IEEE Transaction on Antenna and Propagation, vol. 54, pp.3562-3565, November 2006.

[4] S. Loredo, G. Leon, S. Zapatero, and F Las-Heras, ”Measurement of Low-Gain Antennas in Non-Anechoic Test Sites through Wideband Channel Characterization and Echo Cancellation,” IEEE Antennas and Propagation Magazine, vol. 52, pp. 128-135, February 2009.

[5] R.D. Tamas, G. Vasile, C. Ioana: “A method for antenna gain measurements in nonanechoic sites”, Microwave and Optical Technology Letters, vol. 56, pp.1553-1557, July 2014.

[6] R.D. Tamas, G. Caruntu, D. Popa, “A time-domain measuring technique for ultra-wide band antennas,” Microwave and Optical Technology Letters, vol. 53, pp.281-286, February 2011.

[7] D. Deacu, R.D. Tamas, T. Petrescu, I. Candel, T. Petrut, “On the Accuracy of the Distance-Averaging Method for Antenna Gain Measurements”, IEEE International Workshop on Antenna Technology, pp. 371-374, March 2014.

[8] R.G. Kouyoumjian, P.H. Pathak, ”A uniform geometrical theory of diffraction for an edge in a perfectly conducting surface,” Proceedings of the IEEE, vol. 62, pp. 1448-1461, November 1974.